Traffic-flow & Air Quality Experiment

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Title of paper: Traffic-flow & Air Quality Experiment

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Abstract

The experiment sought to find correlations between traffic management, traffic flow and air quality by measuring the difference between the air pollution levels when cars are waiting for the traffic light to turn green compared to when they are driving through the intersection.

The project succeeded in finding as reliable correlations for NO2 and CO as can be achieved in real-life data gathering. The results showed an increase in local pollution levels, which might be caused by acceleration of cars starting from a standstill or trying to cross the intersection before it turns red.

Keywords: Air Pollution, Traffic Management

Background

The 2025 goal 'Clean air to Copenhageners' is for the municipality to provide knowledge about air pollution through continued measurements in areas where more knowledge is required. Furthermore, there is a need for cooperation with companies on the development of smart solutions based on information about air quality.

In addition, the ‘KBH 2025 Climate Plan’ points to investments in Copenhagen's health and quality of life through clean air by reducing particulate pollution.

Experiment purpose

The overall experiment aim was to understand the potential health benefits of environmentally focused traffic management by regulating traffic to reduce local air pollution.

This could be achieved by finding correlations between traffic management, traffic flow and air quality through measuring the difference between the air pollution levels when the cars are not moving due to a red light compared to when they can drive straight through the intersection.

Experiment design

For the experiment to be scientifically acceptable, so that the results could be used later, an experiment group with the combined necessary skill-sets was formed. It among others consisted of:

- City of Copenhagen: Experiment lead and coordinator
- Technical University of Denmark: Responsible for data processing
- University of Copenhagen: knowledge about air pollution health effects
- Leapcraft: provider of air quality sensors and supporting of data processing
- Citelum, instalment of air quality sensors
- PTV Group and TNO: designers of an environmental quality mobility planning model

This group determined the criteria for the experiment: two comparable intersections that hence had to be similar in design (lanes, width between building facades, number of trees, number of residents in the surrounding area) but were not too close to each other as this could have an impact on data measurements.

Based on these criteria it was determined that the intersection between Ålekistevej / Hyltebjerg Allé and Lykkebovej / Vigerslev Allé were going to be the experiment locations.

The group also decided that for each location the following data sets had to be used:

- Traffic signal regime indicators
  (Indicates whether the signals are red, red/yellow, green or yellow)
- INRIX Traffic dataset / Micro Radar dataset
  (Provide information on the traffic numbers and average speeds at the intersections)
- Atmospheric Pollution dataset
  (Provides information on the pollution levels)
- Weather Underground data
  (Indicates how prevailing weather conditions would affect pollution levels)

Each data set has a different structure and they do not share the same layer of information. The data sets are designed in such a way that they provide context to identify how traffic flow affects air pollution.

Results

Main points of conclusion

While the goal from the outset was to understand the health possibilities of environmentally focused traffic management, this has simply not been possible up until this point due to the delays in the experiment. Yet it was still possible to draw two main conclusions from the measurements made:

1. The plain correlation between air pollution and registered traffic counts were up to 61% for NO2 and 50% for CO depending on the data pre-processing.
   The percentages indicated as reliable correlations as can be achieved in real-life data gathering. These correlations showed during analysis of a predictive model for NO2 and CO concentrations, which disclosed that the model mostly relied on traffic counts and less so the weather conditions.
2. Increase in mean air pollution levels appeared during red/yellow and yellow signals with measurements reaching 9% for NO2 and 113% for CO at the intersection of Vigerslev Alle and Lykkebovej.
   The increases might be caused by acceleration of cars starting from a standstill or trying to cross the intersection before it turns red. However, similar correlations for the second intersection were not observed.

Explaining the data

Comments on data sources

For air quality sensors, around 50% of the data is missing for the period covering 6.00 to 12.00 and around 95% of the data for the period covering 12.00 to 20.00. The inconsistencies were due to battery drainage, provided by the cold Danish weather, and resulted in lower data quality for the morning peak hours and made analysis of the evening peak hours impossible. Therefore, the analysis was restricted to the first half of the day only (00:00 to 12:00).

Visibility and air pressure “clouded” the particle data recordings because the air quality, due to their use of photo optics, was not being able to differentiate between particles types (PM10 – PM1 or waterdrops, salt and similar).

Weather data (air temperature and pressure, relative humidity, visibility, wind direction and speed, etc) were collected from the wunderground.com sensors located within 1 km of the relevant intersections with 10-minute resolution. Recorded air temperature and relative humidity show consistency with the measurements from the Leapcraft sensors.

Traffic data had two sources. First, INRIX provided average travel time through the intersections with 10-minute resolution. Second, micro radars measured number of vehicles and their average speed with 1-minute resolution (for week 15 only). The two data sources show a good relation but the micro radar counts bundled all traffic together.

Finally, traffic signal data (green, yellow, red, yellow/red regimes for all traffic lights) were also provided for both intersections.

Predictive modelling

As a predictive modelling task, the aim was to predict air pollutant concentrations at a given time of day/day of the week as well as to collected weather and traffic data. Several standard machine learning models (linear models, kernel methods and random forest) were tried and their performance estimated using a standard cross-validation approach.

The table below shows the relative decrease of a model's error, when traffic data is used to predict sensor measurements compared to the historical average.

Table 1: MA10 represents moving average of 10 min intervals and LC represents an algorithm developed by Leapcraft for the use of multiple sensors placed near each other.

Pre-processing Techniques	Lykkebovej / Vigslev Allé sensor 1 [%]	Lykkebovej / Vigslev Allé sensor 2 [%]	Ålekistevej / Hyltebjerg Allé sensor 1 [%]
NO2, LC	13.8	53.39	-4.46
NO2, MA10	0.21	7.93	40.21
CO, LC	38.79	22.71	2.85
CO, MA10	18.3	5.53	17.18

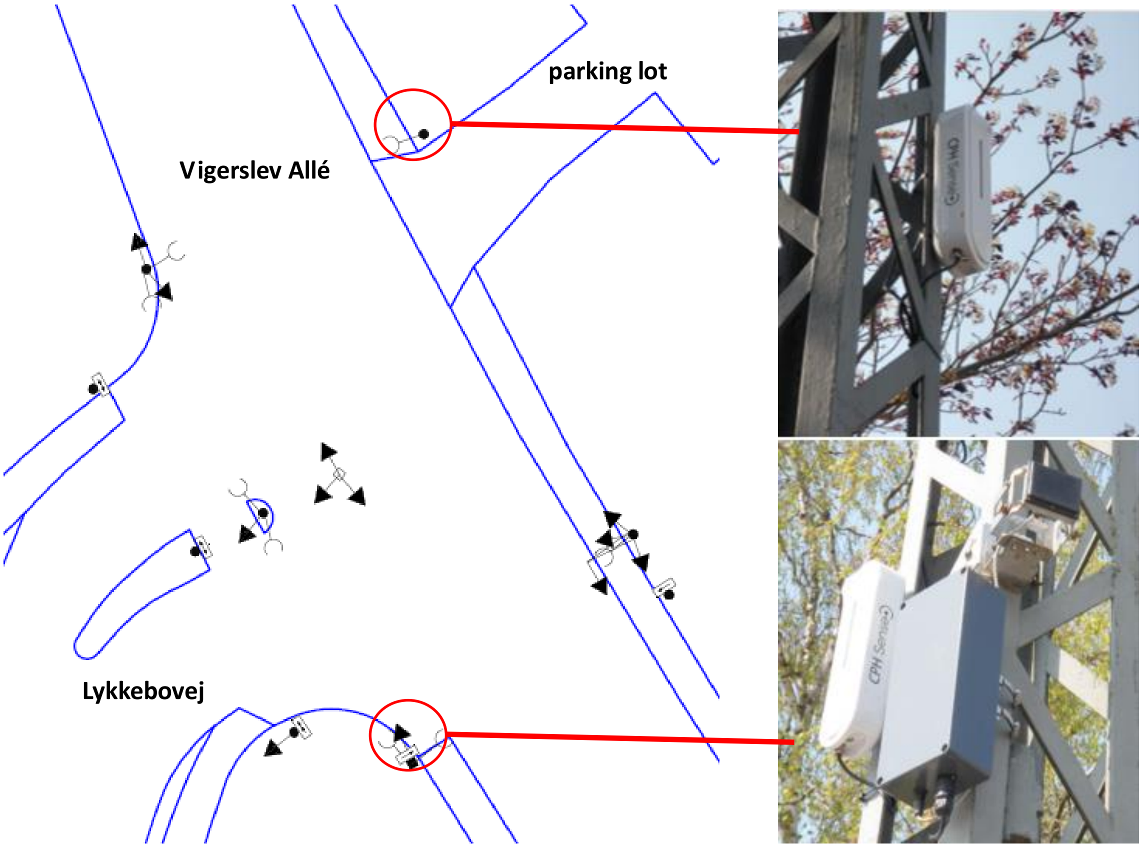
The differences in the performance between the sensors are a result of the difference in location as well as the computations undertaken after the collection of the data. This caused a discrepancy in the improvements and results between the two intersections.

Firstly, the intersections themselves were different in their construction and the dynamics that were measured. Wind and placement of the sensor in addition to the design of the sensor is important for the measurement accuracy. At Ålekistevej / Hyltebjerg Allé (AL), the design of the intersection caused the placement of the sensor to affect the data collected by the system. Consequently, the sensor not only measured the pollution in the intersection but also outside of the intersection.

Secondly, the computations require multiple sensors to improve the overall accuracy of the results. In the intersection AL, the lack of an additional sensor reduced the overall computational accuracy achieved in the system compared to the other intersection.

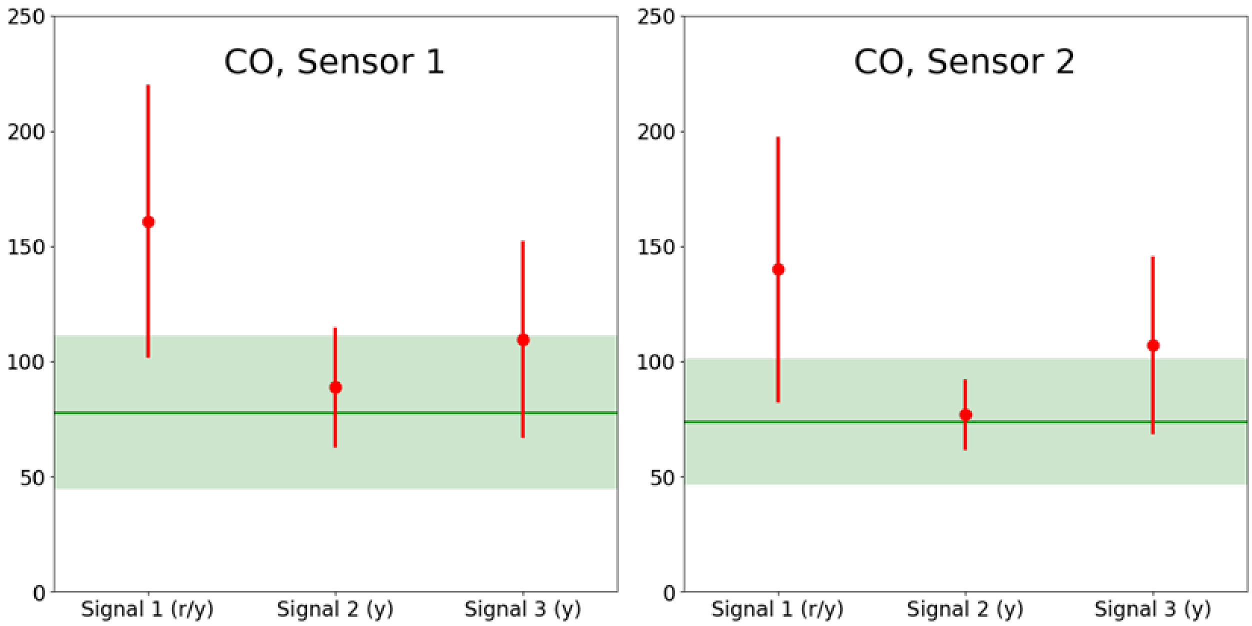
Since the aim is to have higher percentages, as it shows that the model is more predictable, there is a high degree in accuracy in cases when multiple sensors are used. Thus, it was more accurate to investigate the correlation between air pollution levels and traffic signals regimes for the intersection of Lykkebovej / Vigerslev Allé using the Leapcraft's algorithm.

Figure 1-4: Above is a photo of the intersection between Lykkebovej / Vigerslev Allé; Below (left) is a map of the intersection with indications of the air sensor placements (right top and bottom) as well as the micro radar (right bottom).



Means and standard deviation for Vigerslev Allé / Lykkebovej

The illustration below, shows the relative increase of the mean and standard deviation of air pollution levels for NO2 and CO at red/yellow and yellow signal regimes compared to the average level for all regimes (green, yellow, red and red/yellow).



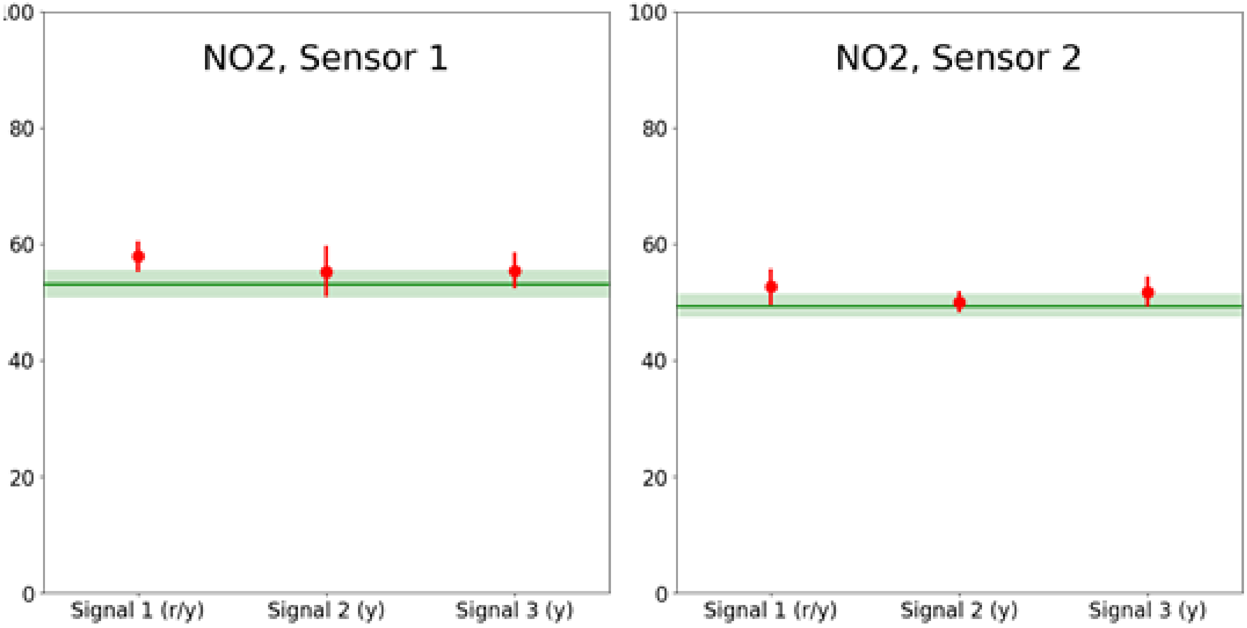


Figure 5-8: the red plot points above indicate the relative increase in pollution levels when traffic signal regimes are red/yellow (r/y) and yellow (y) while the green line indicates the average pollution levels.

The increases indicate that there is a rise in pollution levels for these regimes, which might be caused by accelerating traffic. The precise increase levels can be seen in the table below for the Leapcraft pre-proccesing technique.

Table 2: NO2 increase above average for "accelerating" signal regimes (red/yellow and yellow)

	Sensor 1 [% increase]		Sensor 2 [% increase]	
Signal regime, Signal direction	Mean	Standard Deviation	Mean	Standard Deviation
Red/Yellow, Vigerslev Allé both directions	9	8	7	55
Yellow, In direction of Lykkebovej	4	80	1	-10
Yellow, In direction of parking lot	4	28	5	32

Table 3: CO increase above average for "accelerating" signal regimes (red/yellow and yellow)

	Sensor 1 [% increase]		Sensor 2 [% increase]	
Signal regime, Signal direction	Mean	Standard Deviation	Mean	Standard Deviation
Red/Yellow, Vigerslev Allé both directions	113	78	90	111
Yellow, In direction of Lykkebovej	14	-22	4	-44
Yellow, In direction of parking lot	41	28	45	41

Differences between data results

Predictive modelling results for both intersections are consistent.

However, the correlation patterns between traffic signals and air pollution revealed for the intersection of Vigerslev Allé / Lykkebovej are not detected in the intersection of Ålekistevej / Hyltebjerg Allé. This might be caused by the air sensor placements and the number of sensors used.

Other results

- Data for PM particles (PM 1, 2.5 and 10) contain a lot of noise due to the heavy dependence on weather conditions (mainly visibility), thus it is difficult to find similar correlations for PM particles. However, a small increase in the concentrations for the morning peak hour can be observed.
- The measured SO concentrations were too insignificant to analyse.
- Weather, wind speed and wind direction have little influence on measurements of air pollutants.

Process evaluation

- Generally, the installations of some of the sensor equipment did not have planned procedures and thus there were all sorts of problems between different actors involved in this.
- Challenges with the micro radars have ranged from financial indifferences, to different actors having to be involved at different stages of the installations as well as data safety producers that had to be handled so as not expose the municipal it-system.

- Challenges with the air quality sensors have ranged from battery drainage due to cold weather to problems with data resolution that lead to the sensors having to be taken down and re-calibrated several times.

Lessons learned

Know the administrative processes:

Given that several actors are involved at the different steps of installing a sensor, there is need for a better understanding of the parties' responsibilities and their interactions. If these were to be better planned, the procedures would be shortened significantly and there would be less confusion regarding who should be involved when a certain problem arises.

Advanced data processing is important:

Processing of data sets hinges on the number of air sensors, since it is possible to use other types of algorithms, if two or more are installed in the intersection. At the same time there are also significant indications, that traffic features can significantly improve analysis models. So, although the sample size of the different parameters varies, the raw data sets need advanced cleaning and pre-processing techniques to get useful insight.

Get what you need:

Both the micro radar and air quality sensors have their limitations but they are cheap pieces of measuring equipment and relatively easy to install in a short amount of time. Both technologies are also affordable, which created a foundation and starting point making it possible to learn from it and gain experience that can lead to taking another step.

What the future holds

Scaling the experiment

While the project showed signs that point towards an increase in local air pollution when vehicles accelerate from either a standstill or to "catch a red light", there is still a need for further work to understand if the findings can be applied to a traffic system.

A future project with a traffic corridor should: collect full days of data, identify the use of traffic optimization within a system and find which "trigger" is needed for starting certain traffic management scenarios (number of vehicles or amount of air pollution).

Other factors to be considered when scaling the experiment are:

- Increasing the project time beyond the 6 months, so that there is time for longer periods of measurements that could improve the data analysis processing results.
- Increasing air data resolution to match the traffic signal regime resolution.
- Having constant power in the power source for the air quality sensors, so the problem with battery drainage does not affect the process of measuring.
- Placement of the air sensors should be as close to the “human level” as possible, so that they are exposed to the same layers of air as citizens would be.
- Planning the project period so that it is does not take place during the humid months, so that the humidity factor is lessened in the particle measurements - for example in the summer although there is vacation traffic to consider as an added factor.
- Clarify the sensor instalment process beforehand with all relevant parties, so that a clear plan is layed out and there is agreement on who contacts who in case of problems.
- If technology allows, it would also be very beneficial to identify the different types of particles measured, to know if it was water-based or something harmful.

Other experiments to consider

While this experiment has focused on taking a first step towards creating a data driven traffic management system that can function based on air quality scenarios, there are also other options that could be considered. Examples of such could be; noise pollution, cloudbursts and city events. The idea would then be that some data sets provide the traffic management system with a mechanism for triggering certain protocols that can handle the problem.